Technical Report No. 58

ACARI ON MURINE RODENTS ALONG AN ALTITUDINAL TRANSECT ON MAUNA LOA, HAWAII[1]

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[1] Presented at IV. International Congress of Acarology, Saalfelden, Austria, August 1974; to appear with similar content in the Proceedings of congress.

ISLAND ECOSYSTEMS IRP

U. S. International Biological Program

April 1975

ABSTRACT

Rodents were trapped seasonally during a two-year period at 14 primary sites from 840 to 2440 m on a transect (with additional collecting to 2895 m), and intensively collected in the Kilauea Forest near the transect. The sampled habitats were not in the proximity of human habitations. Three of the four murine species present in the Hawaiian Archipelago were taken: _Mus musculus_, _Rattus rattus_, and _R. exulans_. Ectoparasites were recovered from rodents by a standardized washing technique. Mammalogical and parasitological data were analyzed by computer. The occurrence, host associations, and spatial distribution of some Acari are treated here. Significant correlations, including those for some permanently parasitic mites, are partially independent of host factors and are associated with local differences in climate.

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INTRODUCTION

This study is part of the Island Ecosystems Integrated Research Program under the U. S. International Biological Program. Research involving investigations in varied disciplines has been concentrated primarily over a range of altitudes in and near Hawaii Volcanoes National Park on the southeastern slope of Mauna Loa, Hawaii Island.

Previous quantitative studies of ectoparasites in Hawaii have concentrated on single habitats (e.g. Mitchell 1964a, 1964b) and have not utilized altitudinal transects. The study area presents an unusual opportunity to examine the influence of various physical and biotic parameters on the distribution of ectoparasites associated with rodents that are usually domiciliated or at least primarily restricted to areas modified by man. In the absence of a fauna of native land mammals, introduced mammals in Hawaii have occupied habitats from which they would normally be excluded by competing species in continental areas. This is particularly evident in the case of rodents, especially the Roof Rat, *Rattus rattus*, and the House Mouse, *Mus musculus*. *M. musculus* appears to be the most successful in the variety of habitats utilized and in total numbers. Closed rain forest is only marginally suitable for *M. musculus*, while *R. rattus* reaches its highest densities in rain forest. However, *R. rattus* also appears in drier situations including grasslands. Both species occur at high altitudes (Tomich 1969); during our current study, *R. rattus* was taken up to 2440 m and *M. musculus* up to 2895 m.

The third species involved in this study is the Polynesian Rat, *Rattus exulans*, a tropical species rarely occurring above 1220 m on Mauna Loa and restricted to wetter habitats. *R. exulans* is basically a less commensal species than the two noted above and regularly occurs in "natural" situations throughout its Pacific range.

The Brown Rat, *Rattus norvegicus*, is a lowland species in Hawaii and is largely restricted to environments modified by man; it was not taken. The Small Indian Mongoose, *Herpestes auropunctatus*, was examined for ectoparasites, but no Acari were recovered.

All groups of ectoparasites are considered in this study, which is still in progress at the time of writing; in particular, the data already assembled are not fully analyzed. In this report, we concentrate on the Acari and on some of the more striking aspects of their spatial distribution, host associations, and new records.

MATERIALS AND METHODS

Hawaii Island lies for the most part between 19° and 20°N latitude. On the slope of the Mauna Loa Transect, the climate near sea level is tropical with a mean annual temperature of 22.8°C (Hilo) and a high rainfall. Along the transect, the trend is to lower rainfall and lower temperature with increasing altitude (Doty and Mueller-Dombois 1966). Above the tree line, the climate is dry and there are frequent night frosts. Approaching the summit of Mauna Loa (4107 m), there is stone desert without established vegetation. Because two separate weather fronts converge in the transect area, slight lateral deviation can result in major differences in rainfall. Consequently, some trap lines at moderately high elevations are classified as relatively wet and some at low altitudes are relatively dry. This permits evaluation of the effects of moisture independent of altitude and, hence, temperature. For a vegetational analysis of the trapping sites on the Mauna Loa Transect, see Jacobi (1974).

Trapping was carried out regularly with 14 lines of 39 traps (2/3 cage-type live traps and 1/3 snap traps) on or close to the main Mauna Loa Transect and from 840 to 2440 m, during the period October 1971 through September 1973. Nine of the 14 lines were run each year--10 lines during the 1st or the 2nd year and four during both years. Three lines were operated each month on a rotating basis, so that a line was sampled four times, at three-month intervals, during a year. Irregular trapping with snap traps was conducted at about 150 m intervals above 2440 m to 3050 m.

Regular and intensive trapping was carried out each month in the Kilauea Forest (1645 m), using two 60-trap lines, over a 24-month period beginning three months earlier than on the Mauna Loa Transect. Although not part of the Mauna Loa Transect, the Kilauea Forest site provided important comparative data on ectoparasites in a homogeneous closed primary montane forest with a distinctly higher rainfall than at comparable elevations on the transect.

Many animals examined mammalogically were not sampled for ectoparasites, usually because of poor condition--e.g., when overrun by ants. Some animals recorded as in poor condition were sampled for ectoparasites; these are not included in this report except where so stated.

Animals from both live and snap traps were placed in plastic bags with chloroform when picked up in the field. In the field laboratory each animal was washed in a detergent solution; all ectoparasites were recovered from the liquid, transferred to alcohol, and shipped to the base laboratory for identification and counting. The washing procedure was standardized to achieve consistent sampling efficiency. For most groups it provided a high rate of recovery, e.g. the respective numbers of two Laelaps spp. per infested Rattus are comparable to those recorded by Mitchell (1964b) using a skin digestion method elsewhere in Hawaii.

All mammalogical and parasitological data were coded, and listed and analyzed by computer.

RESULTS AND DISCUSSION

Fur Mites (Listrophoroidea and Myobiidae)

The most striking apparent anomaly in local spatial distribution involved two species of listrophoroid fur mites. Afrolistrophorus musculus (Wilson and Lawrence 1967) (Listrophoridae), transferred from Listrophorus by Fain (1970), is a common parasite of Mus musculus in the Hawaiian Islands; but it is unknown elsewhere except for records from the same host in Puerto Rico by Tamsitt and Fox (1970). Listrophoroides cucullatus (Trouessart 1893) (=Listrophoroides expansus Ferris 1932 - cf. Fain 1972) (Atopomelidae) is widely distributed on Rattus spp. in tropical and subtropical areas.

Table 1 shows the distribution of these two parasites by trap lines. There was a remarkably abrupt altitudinal limitation, with neither of the mites occurring above 1220 m, while the incidence on most lines at 1220 m or lower was moderate to high.

Contrastingly, four other species of fur mites showed no indication of altitudinal restriction (Table 2). Radfordia ensifera (Poppe 1896) (Myobiidae) was found up to the limit of the distribution of R. rattus, and in the Kilauea Forest 25.5% of 263 R. rattus were infested. On Mus musculus, the three other species also occurred up to the highest altitude (2895 m) where the mice were collected; at 1845 m, the following percentages of 55 mice were infested with these parasites: Myobia musculi (Schrank 1781) - 52.7% and Radfordia affinis (Poppe 1896) - 50.9% (Myobiidae), Myocoptes musculinus (Koch 1884) - 27.3% (Listrophoroidea: Myocoptidae).

Table 1. *Afrolistrophorus musculus* and *Listrophoroides cucullatus* on Rodents on Mauna Loa Transect, Oct. 1971-Sept. 1973.*

			Afrolistrophorus musculus on *Mus musculus*			*Listrophoroides cucullatus* on *Rattus rattus*			*Listrophoroides cucullatus* on *Rattus exulans*		
Trap line	Elevation (Meters)	Period (year 1 and/or 2)	Rodents examined	% infested	Mites/ infested host	Rodents examined	% infested	Mites/ infested host	Rodents examined	% infested	Mites/ infested host
11 + 12	2895 2745	2	3	0	-	0	-	-	0	-	-
10	2440	2	14	0	-	1	0	-	0	-	-
1	2135	1	9	0	-	3	0	-	0	-	-
2	1845	1 + 2	55	0	-	3	0	-	0	-	-
Kilauea Forest	1645	1 + 2	12	0	-	263	0	-	0	-	-
3	1495	1 + 2	43	0	-	10	0	-	0	-	-
4	1280	1	35	0	-	3	0	-	0	-	-
5	1220	1	10	0	-	0	-	-	0	-	-
15	1220	2	12	58.3	79.6	22	0	-	1	0	-
16	1220	2	3	33.3	3.0	35	25.7	15.6	4	0	-
6	1190	1 + 2	4	25.0	38.0	46	43.5	15.0	4	25.0	4.0
8	900	1	38	63.2	70.5	10	80.0	67.9	11	45.5	55.8
9	900	1	9	66.7	7.8	3	100	87.0	14	78.6	37.7
7	870	1 + 2	73	45.2	36.7	9	33.3	12.3	3	100	49.3
17	870	2	21	47.6	3.3	12	41.7	7.0	0	-	-
18	840	2	29	20.7	11.3	2	0	-	0	-	-
Total**		1 + 2	358	24.6	39.9	159	30.2	27.4	37	54.1	42.3

* The 2 listrophoroid species exhibited a high level of host specificity at the generic level: *A. musculus* was recovered from 2 *R. rattus* and 1 *R. exulans*; *L. cucullatus* was recovered from 2 *M. musculus*. All but 1 of these incidents involved a single mite and probably resulted from contamination in recovery process.

** Excluding Kilauea Forest.

Table 2. Incidence (%) of two rodent species infested with various species of fur mites (Myobiidae and Listrophoroidea) on Mauna Loa Transect, Oct. 1971-Sept. 1973.*

		Mus musculus					*Rattus rattus*		
Trap line	Elevation (meters)	No. examined	*Myobia musculi*	*Radfordia affinis*	*Myocoptes musculinus*	*Afrolistrophorus musculus*	No. examined	*Radfordia ensifera*	*Listrophoroides cucullatus*
11 + 12	2895 2745	3	100	66.7	33.3	0	0	-	-
10	2440	14	42.9	50.0	7.1	0	1	100	0
1	2135	9	88.9	77.8	33.3	0	3	0	0
2	1845	55	52.7	50.9	27.3	0	3	0	0
Kilauea Forest	1645	12	50.0	41.7	66.7	0	263	25.5	0
3	1495	43	37.2	37.2	53.5	0	10	50.0	0
4	1280	35	54.3	54.3	48.6	0	3	66.7	0
5	1220	10	60.0	50.0	40.0	0	0	-	-
15	1220	12	8.3	25.0	16.7	58.3	22	9.1	0
16	1220	3	33.3	0	0	33.3	35	5.7	25.7
6	1190	4	0	0	0	25.0	46	34.8	43.5
8	900	38	42.1	42.1	55.3	63.2	10	30.0	80.0
9	900	9	22.2	11.1	55.6	66.7	3	66.7	100
7	870	73	37.0	43.8	28.8	45.2	9	44.4	33.3
17	870	21	85.7	57.1	47.6	47.6	12	58.3	41.7
18	840	29	65.5	58.6	34.5	20.7	2	100	0

* Rodents recovered in poor condition are not included even though examined for ectoparasites.

It is not tenable that R. exulans is the maintaining host of L. cucullatus, thereby limiting the range of the mite. L. cucullatus occurred on R. rattus on several lines where R. exulans was rare or absent, and the mite is found elsewhere in the world outside of the range of R. exulans. In any case, this hypothesis does not have a parallel that could explain the altitudinal restriction of A. musculus on Mus.

A. musculus and L. cucullatus are small permanent parasites on a homeothermic host, and we are accustomed to thinking of such parasites as being insulated from ambient climatic conditions. However, the available evidence suggests to us that temperature, here associated with altitude, is the mediating factor in determining these local distributions. To our knowledge, this is the first instance of evidence based on local distribution in nature for temperature as a factor influencing the ranges of permanent parasites among the Acari.

Under the conditions of the study area, approximately 16°C appears to be the limiting mean annual temperature (i.e. at 1220 m) for these mites. This may apply only on the lower slopes of Mauna Loa and similar areas where, despite a degree of N latitude seasonality, the temperature is relatively constant throughout the year; at 1280 m and presumably also below that altitude, mean daily temperature fluctuations exceed seasonal fluctuations in mean daily temperature (unpublished IBP data).

Without laboratory experimentation, we may only hypothesize tentatively concerning how temperature might influence the mites. It could be indirect, influencing the physiology of the host. However, we suggest that temperature has a direct influence on the mites. A. musculus and L. cucullatus are very elongate parasites, while the other fur mites in this study are relatively compact in form. Elongation increases surface area relative to mass and thereby reduces the ability to conserve heat. Possibly the longer body results in part of the mite being further from the host skin. Elongation presumably confers advantages on the parasite, and perhaps it is associated with a behavioral tendency to migrate up and down on hairs and even to move about more among the hairs, also tending to remove the parasite from proximity with the skin surface. Distinctly higher numbers of A. musculus and L. cucullatus recovered per host, compared to the other fur mites, may relate to such behavioral differences.

The relatively recent discovery of a common parasite in and apparently restricted to Hawaii, on an introduced cosmopolitan host, in the case of

Afrolistrophorus musculus on Mus musculus, remains puzzling despite the later record from the West Indies. A similar case has appeared in Hawaii with the discovery of the previously undescribed Lynxacarus radovskyi Tenorio 1974 (Listrophoridae) on domestic cats, first on Oahu (Kawamura 1974, as determined by Dr. F. Haramoto) and about 6 months later on Kauai (Radovsky and Tenorio, in press). The production of mange in some of the infested cats suggests that the host-mite relationship may be recent and hence ill-adapted. However, the source of the mites remains obscure.

Laelapidae

Laelaps (Echinolaelaps) echidnina Berlese, 1887 and L. (Laelaps) nuttalli Hirst, 1916 (Laelapidae: Laelapinae) were taken on Rattus rattus up to 1645 m (in the Kilauea Forest). Complete lack of records above this altitude, at least for L. echidnina, probably results from the meager sampling (7 R. rattus). L. nuttalli occurred throughout the range in which R. exulans was taken (to 1220 meters), but L. echidnina was found on only one individual of this host species, on line 7 (870 m). Rarity of L. echidnina on R. exulans contrasts with the results of Mitchell (1964b), who found the mite to be higher in both incidence and intensity of infestation on R. exulans than on R. rattus at low altitudes on Oahu (Manoa Valley).

The most interesting contrasts in infestation of Laelaps species on R. rattus are between the Kilauea Forest site and the transect trap lines. Incidence of L. echidnina in the Kilauea Forest was 26.6% (70/263) with $\bar{X}$ 4.8/infested host; on the transect, incidence was 12.2% (13/159) with $\bar{X}$ 2.7/infested host. Corresponding figures for L. nuttalli are 4.9% (13/263) and $\bar{X}$ 1.9 in the Kilauea Forest, and 52.8% (85/159) and $\bar{X}$ 52.8 on the transect.

L. nuttalli is widely distributed, but principally occurs in tropical and warm temperate areas. Mitchell (1964b) found a higher incidence and intensity of this species on Rattus spp. compared to L. echidnina on the same hosts in Manoa Valley, as we did on the lower portion of the transect. The low populations of L. nuttalli in the Kilauea Forest are probably associated with temperature. The relatively high populations of L. echidnina in Kilauea Forest may relate to several factors. The absence of competition from L. nuttalli as well as climatic factors could be involved.

Hypoaspis species (Laelapidae: Hypoaspidinae) are often associated with vertebrates or their nests but are generally considered to be nonparasitic. The two most numerous in this study were Hypoaspis sardoa (Berlese 1911) and Hypoaspis nidicorva Evans and Till, 1966. H. sardoa has been previously reported only from the Palearctic Region in litter, in nests, and more rarely on bodies of murid and cricetid rodents. This is apparently the first published record of the species on Rattus or Mus. H. nidicorva was previously recorded only from the nest of a Corvus species in England. Our identification (Radovsky and Tenorio 1974) extends the geographic range of H. nidicorva into the Pacific and the host association to mammals.

Hypoaspis sardoa was far the most abundant species of this genus on rodents. R. rattus in the Kilauea Forest had an incidence rate of 20.9% and $\bar{X}$ 2.1/infested host; these figures for the transect were 15.1% and $\bar{X}$ 1.7. H. sardoa was more abundant at higher altitudes and was taken up to 2135 m. The numbers dropped particularly in the drier lines at low elevation. It appears that this species does best in a cool and moist environment. It occurred at about the same rate on R. exulans within the range of that host. It was rare on Mus musculus.

H. nidicorva had an incidence of 8.7% and $\bar{X}$ 1.6 on R. rattus in Kilauea Forest, and it was rare on the transect. The greater numbers in the Kilauea Forest suggest that this species is adapted to cooler temperatures if not necessarily moist environments.

Hirstionyssus butantanensis (Fonseca 1932) [=H. latiscutatus (de Meillon and Lavoipierre, 1944) - cf. Herrin 1974] (Laelapidae: Hirstionyssinae) is a widely distributed parasite of various murids and has been recorded principally from domiciliated Mus and Rattus. Here again, the highest parasitization was in the Kilauea Forest, where R. rattus had an incidence of 25.5% and a $\bar{X}$ 6.8/infested host; there, a single mite was recovered from each of 2 of the 12 individuals of M. musculus examined.

On the transect, H. butantanensis occurred on R. rattus sporadically with an incidence of 3.1% and $\bar{X}$ 1.4. All records were from the wetter lines. This mite was not found on R. exulans. The distribution on M. musculus is interesting, with an incidence of 13.2% (5/42) on line 8--one of the wettest transect lines and at relatively low elevation--and only 2 other individual mites taken on other lines. No mites of this species were recovered from R. exulans.

It appears that high moisture is a requisite for this mite. The results also suggest that Rattus rattus is a more nearly optimal host than Mus musculus.

Macronyssidae

Ornithonyssus bacoti (Hirst 1913) was restricted to the three lowest lines of the transect, 7, 17, and 18 at 870, 870, and 840 meters, respectively, and was taken only on Mus musculus. Of 123 Mus on these 3 lines, 31.7% were infested (Table 3). As a single exception to this restricted distribution, one mite was taken on one of 42 M. musculus (inclusive of animals recovered in poor condition) examined on line 8 (900 meters).

The three lines where O. bacoti occurred in significant numbers are the driest of the lower trap lines on the transect, and they also have common vegetational features--open forest and grassland. However, on wet line 8, also with open forest, only a single O. bacoti was recorded on the 42 M. musculus. O. bacoti appears to have a higher tolerance for moderately low humidities than many other nest mites, and this study indicates that high moisture levels can preclude its presence under natural circumstances.

The failure to recover O. bacoti from R. rattus and R. exulans in the same environments where it occurred on M. musculus is surprising. Only three R. exulans were examined from lines 7, 17, and 18, but 23 R. rattus were examined from these lines. Mitchell (1964) found an incidence of O. bacoti of 17.2% on R. rattus (64 examined) but only 4.0% on R. exulans (25 examined) in his low altitude study on Oahu.

Nasal Mites (Ereynetidae)

Two species of nasal mites (Ereynetidae: Speleognathinae) were recovered from rodents using a nasal-flushing technique. Both are new records for Hawaii. Paraspeleognathopsis bakeri (Fain 1955) was taken from 41% (20/49) of M. musculus examined. It has been previously recorded from a variety of murids and some other mammals, but not from Mus (Fain 1970). Speleorodeus derricki (Womersley 1954) was found in 9 of 42 R. rattus and 2 of 9 R. exulans examined; it has been recovered from Rattus spp., including R. rattus, elsewhere.

ACKNOWLEDGEMENTS

We are grateful to Professor A. Fain for providing initial determinations of the two species of nasal mites.

Table 3. Occurrence of Ornithonyssus bacoti on Mus musculus on three trap lines, Mauna Loa Transect, Oct. 1971-Sept. 1973.*

Trap line	Elevation (meters)	Period (year 1 or 2)	Rodents Examined	% infested	Mites/ infested host
7	870	1	29	27.6	1.5
7	870	2	44	29.5	2.5
17	870	2	21	47.6	2.6
18	870	2	29	27.6	5.1
Total		1 + 2	123	31.7	2.8

* Rodents recovered in poor condition are not included even though checked for ectoparasites.

LITERATURE CITED

Doty, M. S. and D. Mueller-Dombois. 1966. Atlas for Bioecology Studies in Hawaii Volcanoes National Park. Univ. of Hawaii. Hawaii Botanical Sciences Paper No. 2. 507 p.

Fain, A. 1970. Diagnoses de nouveaux Lobalgides et Listrophorides (Acarina: Sarcoptiformes). Rev. Zool. Bot. Afr. 81: 271-300.

Fain, A. 1970. Notes sur les spéléognathines parasites nasicoles des mammiferes (Ereynetidae: Trombidiformes). Acarologia 12(3): 509-521.

Fain, A. 1972. Les Listrophorides En Afrique Au Sud Du Sahara (Acarina: Sarcoptiformes) III. Famille Atopomelidae. Ann. Mus. R. Cent. Afr. 8° Sci. Zool. n° 197: 1-200.

Herrin, C. Selby. 1974. The taxonomic status of *Hirstionyssus butantanensis* (Fonseca, 1932) (Acari: Mesostigmata). J. Med. Ent. 11(3): 341-346.

Jacobi, James D. 1974. A vegetational description of the IBP small mammal trap-line transects - Mauna Loa Transect. Island Ecosystems IRP/U. S. International Biological Program. Tech. Rep. No. 48. ii + 19 p.

Kawamura, K. F. 1974. Notes and Exhibitions. Proc. Hawaii. Ent. Soc. 21(3): 321.

Mitchell, Carl J. 1964a. Ectoparasitic and Commensal Arthropods Occurring on the Rats of Manoa Valley, Oahu (Acarina, Anoplura, and Siphonaptera). Proc. Hawaii. Ent. Soc. 18(3): 413-415.

Mitchell, Carl J. 1964b. Population structure and dynamics of *Laelaps nuttalli* Hirst and *L. echidninus* Berlese (Acarina: Laelaptidae) on *Rattus rattus* and *R. exulans* in Hawaii. J. Med. Ent. 1(2): 151-153.

Radovsky, F. J. and J. M. Tenorio. 1974. Notes and Exhibitions. Proc. Hawaii. Ent. Soc. 21(3): 306.

Radovsky, F. J. and J. M. Tenorio. Notes and Exhibitions. Proc. Hawaii. Ent. Soc. (in press).

Tamsitt, J. R. and I. Fox. 1970. Mites of the family Listrophoridae in Puerto Rico. Canad. Z. Zool. 48: 398-399.

Tenorio, JoAnn M. 1974. A new species of *Lynxacarus* (Acarina: Astigmata: Listrophoridae) from *Felis catus* in the Hawaiian Islands. J. Med. Ent. 11(5): 599-604.

Tomich, P. Quentin. 1969. Mammals in Hawaii. B. P. Bishop Mus. Special Publ. 57. 238 p.

TECHNICAL REPORTS OF THE US/IBP ISLAND ECOSYSTEMS IRP

(Integrated Research Program)

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